Industrial College of the Armed Forces
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Construction

ABSTRACT

The construction industry grew at a moderate pace during the last twelve months, in spite of a weakening economy and chronic shortages of skilled and semi-skilled labor. The economic stimulus package adopted in the wake of the September 11th terrorist attacks – notably a series of interest rate reductions - resulted in a sharp increase in housing construction and renovation, offsetting a downward trend in commercial construction. The terrorist attacks also stimulated a renewed interest in applied research and development aimed at improving materials and construction techniques to mitigate the potential damage of future terrorist attacks on American infrastructure. Industry data show evidence of a continuing trend towards consolidation through acquisitions and mergers, forcing smaller construction-related companies to increase their productivity to remain competitive. This trend is driving an accelerated use of information technology tools, particularly at the interface between construction design and scheduling, in an industry-wide effort to improve the efficiency and predictability of project delivery. Finally, as State and local governments find it increasingly difficult to raise revenues to build and maintain needed infrastructure, alternative financing mechanisms involving the private provision of traditionally public services are becoming more widespread.

The construction industry demonstrated its resiliency and surge capacity with its yeoman response to the exceptional clean up and reconstruction requirements at the Pentagon and World Trade Center disaster sites. There are no overriding concerns about the readiness of the construction industry to contribute to national security or national mobilization in the event of future conflicts. The industry is generally healthy, moderately profitable, and industry analysts expect continued growth in housing, commercial construction and heavy construction over the medium and long-term.

Mr. Andrew Bewick, DIA
CDR Mark Boettcher, USN
Mr. Julian Bott, EADS
CDR William Condon, USN
Mr. Kenneth Eads, NSA
COL Gary Harter, USA
LtCol Arnold Holcomb, USAF
COL Juris Kiukucans, Latvian Army
LTC Bill Laster, USA
Mr. Alec Mally, State Dept.
COL Paul Meredith, USA
LTC William Perkins, USA
LtCol Michael Smietana, USAF
Ms. Deborah Tomsic, DCMA
Mr. Brad Wallach, USAID

Dr. Hugh Conway, Faculty Lead
Capt. Norman Henslee, USCG, Faculty
Dr. Paul A. Brown, DA

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PLACES VISITED

Domestic
Associated General Contractors of America, Alexandria, VA
Boston Harbor – Central Artery Tunnel Project, MTA, Boston, MA
Parsons-Brinckerhoff, New York, NY
Pentagon Renovation Project, Arlington, VA
Sheet Metal Workers Union, Local 100, Suitland, MD
Stromberg Sheet Metal Works, Beltsville, MD
Department of Transportation and Public Works Municipal Bridge Project, San Juan, PR
Jacksonville Harbor Deepening Project, Jacksonville, FL
Palm Valley Bridge Project, Jacksonville, FL
Rotary Club of San Juan, San Juan, PR
Tren Urbano Subway Project, San Juan, PR
U.S. Army South, San Juan, PR
U.S. Coast Guard Housing Project, San Juan, PR
U.S. Coast Guard Barracks Construction, San Juan, PR
U.S. Corps of Engineers, Jacksonville District, Jacksonville, FL
U.S. Federal Courthouse, Jacksonville, FL
Virginia DoT, Springfield Interchange Project, Springfield, VA
World Trade Center, New York City, NY

International

Taipei, Taiwan:
Technical Liaison Section, AIT
National Defense University – Taiwan
Ministry of Transportation and Communications
Bureau of Taiwan High Speed Rail
Department of Rapid Transit Systems, Taipei City Government
Taipei Rapid Transit Corporation
Taiwan High Speed Rail Corporation
Bangkok, Thailand:
U.S. Embassy, Thailand
American Chamber of Commerce, Bangkok
New Bangkok International Airport
Gammon Skanska, Thailand
Ministry of Science, Technology and the Environment
Metropolitan Electricity Authority
Samut Prakarn Wastewater Management Project
Shanghai, China:
American Consulate, Shanghai
Bechtel Corporation (IBM Plant Construction Site), Shanghai
American Chamber of Commerce, Shanghai
Urban Planning Exhibit, Shanghai

INTRODUCTION

The construction industry builds the public and private sector infrastructure upon which U.S. commerce (and virtually all other industries) depends. The "built environment" forms the core of our way of life. The construction industry is critical to national security because it supports mobilization, forward presence and power projection. The capacity of the industry to surge in time of need - to build ports, airfields, paved roads, barracks and countless other military-related structures and facilities - is clearly essential to our war-fighting capability.

The construction industry study seminar conducted a very broad-based review of the industry. We engaged in discussions with representatives of the global top 10 construction companies; general contractors; trade unions; construction equipment manufacturing companies; professional associations; industry lobbyists; research institutions; U.S. and foreign governmental agencies; and many other industry actors and activists. The terrorist attacks of September 11th influenced the tone of our discussions and provided one of the overarching themes for our industry analysis. Our domestic and foreign travels allowed us to experience, first-hand, the challenges associated with the construction of major civil works (bridges, tunnels, subway systems, airfields, ports, roads and waterways, among others) and to gain an appreciation for the competitive conditions under which construction firms must operate in both domestic and international markets. Our assessment of the current status of the industry, which follows, is based in large measure on these discussions and field observations.

THE INDUSTRY DEFINED

Structure. The construction industry accounts for nearly 8% of U.S. Gross Domestic Product (GDP)[1]. The industry is comprised of firms primarily engaged in construction work that have one or more paid employees. Construction management firms are also included. Most construction firms are small, the majority employing fewer than ten workers. The United States is one of the leading construction markets in the world, employing 6.8 million workers in 2001[2]. Employment in this industry is concentrated in industrialized and highly populated areas.

The industry is divided into three major segments: (1) general building contractors, (2) heavy construction contractors, and (3) special trade contractors. According to the Bureau of Labor Statistics, there were about 667,000 construction companies in the United States in 1997. Of these, 197,000 (30 percent) were general contractors and builders, 38,000 (5 percent) were heavy construction or highway contractors, and 432,000 (65 percent) were special trade contractors[3]. As indicated by these figures, the largest concentration, in terms of the number of contractors, is in the special trades segment of the industry. However, the largest concentration based on revenue is in the general contractor segment. By industry segment (based on 2000 figures), the special trade contractors employ almost 64 percent of the construction workforce (4.3 million workers), while the general contractors and heavy construction contractors employ about 23 percent (1.5 million workers) and 13 percent (900,000 workers) respectively[4].

Conduct. Most of the workers in construction are skilled crafts workers or laborers, helpers, and apprentices who assist the more skilled workers. Most construction workers are classified as structural, finishing, or mechanical workers. Despite its size, the construction workforce is by no means monolithic. Employment in construction is cyclical and seasonal, leading to pronounced

swings in the number of workers employed over the course of a year. The construction industry is a labor-intensive industry and has always been so. In spite of the fact that construction wages have not increased significantly in recent years, construction remains one of the highest paying industries, as measured by hourly and weekly earnings. The average hourly earnings of workers in construction were $17.88 in 2000, compared to an hourly average of $13.75 for all workers[5]. Union membership in the construction industry tends to be higher than many other industries. In 2001, 18.4 percent of construction workers belonged to unions, compared to only about 14 percent of all American workers[6].

The construction industry lags behind other industries in research and development (R&D) investment. According to the Civil Engineering Research Foundation (CERF), U.S. R&D investment amongst mature companies is 3.5 percent of sales; for industries such as aerospace, computers, and biotechnology, that number can be 7 to 14 percent. However, the construction industry only reinvests 0.5 percent of sales. The reasons for the low reinvestment vary, but are generally due to the fact that construction-related R&D and the commercialization of resulting innovative technologies is sometimes seen as a luxury that the firm cannot afford, given the industry's notoriously low profit margins, procurement procedures, and liability concerns.

Annual military-sponsored, construction-related R&D spending (approximately $60M) represents a small fraction (11 percent) of all federal construction-related R&D spending ($545M), and is only a minor fraction (0.001 percent) of DoD's total annual R&D budget ($50B)[7].

The US Army Corps of Engineers (USACE), through the Construction Engineering Research, Geotechnical and Structures, and Information Technology Laboratories, contributes most to DoD's construction-related R&D initiatives. However, despite a projected total federal R&D budget increase of 15 to 20 percent by 2005, USACE's projected overall budget decrease of 24.9 percent by 2006 suggests DoD's construction-related R&D will decrease over the next few years as it continues to concentrate on its core war-fighting competencies[8]. The US Navy's Naval Facilities Engineering Service Center also contributes significantly to DoD's construction-related R&D.

Over the past twenty years the preferred method for developing and delivering construction projects has been changing. Recently the trend has been toward more use of design-build project delivery. Design-build is a method of project delivery in which one entity (design-builder) forges a single contract with the owner to provide for architectural/engineering design services and construction services. By contrast, with the "traditional" design-bid-build approach, the owner commissions an architect or engineer to prepare drawings and specifications under a design contract, and subsequently selects a construction contractor by competitive bidding (or negotiation) to build the facility under a construction contract.

Until recently, a tendency in the construction industry has been for general contractors to push risk down to sub-contractors and require the subs to carry third-party insurance coverage, raising costs and eroding profit margins. As a result of subcontractor resistance, this tendency is being reversed and risk more broadly shared.

CURRENT CONDITIONS

Performance. Despite the sluggish U.S. economy, the performance of the construction industry remained strong through early 2002. Contracting for new construction in January 2002 increased 2 percent[9]. The value of construction put in place in the year ending December 31, 2001 totaled $864 billion, up 3% from the year ending December 2000[10]. An important factor behind the strength of the construction industry has been an offsetting pattern by project type. The weakening employment picture and credit tightening led to declines for commercial building, yet further expansion was reported for highways, bridges, electric power plants, and schools. Strength in the residential housing market, triggered by mortgage interest rate reductions, essentially matched the healthy pace achieved in 2000.

The construction industry has historically low profit margins, but the trend is improving. After tax profits were less than 3 percent of income (less materials) in 1991 and just under 9 percent in 2000. During the same period, income doubled. Special trade contractors performed particularly well, achieving a 24.2% jump in profits over 1999's previous record of $43.68 billion[11].

Generally, the construction industry is closely tied to the overall health of the U. S. economy. However, the mild recession led to lower interest rates, which translated into stable workloads and continued profitability. Additionally, sustained and steady growth in the U. S. population has continued to feed a demand for housing, business, and infrastructure that have added further stability to this industry. Post 9/11 spending to retrofit security enhancements for critical infrastructure has provided additional stimulus.

Key to meeting these demands has been an increased reliance on immigrant labor, primarily from Mexico and Latin America. While native-born Americans increasingly choose college over the trades, the industry has turned to immigration to meet labor demands. And, in spite of the widespread impression that the construction industry is not technology-based, the industry is slowly progressing towards increased reliance on and use of information technologies to maintain competitiveness.

International Competitiveness. The United Nations estimates that construction is the world's largest industrial employer with 111 million employed globally[12]. The best data on the size of the global market is from a bi-annual private industry survey – placing the market at $3.41 trillion at the start of 2001[13]. It is estimated that this number will grow by 3 percent to bring the market to over $3.5 trillion by the start of 2003.

In general, most construction labor is sourced in countries where the jobs are performed and not shipped overseas from the United States. Thus U.S. construction firms export primarily construction management expertise. Half of the top 100 U.S. firms work internationally, specializing in project management and high tech sectors, especially energy infrastructure, where the projects often involve large U.S. equipment exports. While U.S. firms are competitive on general infrastructure projects, global competition for mega-projects is intensifying.

The U.S. is running a moderate trade surplus in construction services, equal to $4.83 billion in 2000, with imports a mere $422 million that year.

The global outlook for the construction industry varies by region, depending on local and regional economic conditions. For example, the Asian financial crisis of 1997-98 is still creating a drag on the region's construction. It remains important for the U.S. government to press for more open international trade in services via the World Trade Organization, and bilaterally, where possible.

Finally, this industry remains quite fragmented, but is in the process of consolidating[14]. Acquisitions are becoming the norm as firms compete to expand market share and corporate capacity and competence. These consolidations allow the industry to take on ever more complex projects in both domestic and international markets.

MAJOR CHALLENGES

Skilled Labor. The construction industry is facing an unprecedented nationwide shortage of skilled and semi-skilled labor. A Construction Industry Institute study shows that 75% of contractors are experiencing severe labor shortages[15], resulting in cost overruns and schedule delays. In 1998, the U.S. Department of Labor predicted shortages of skilled workers throughout the next decade. The report indicated there would be no increase in the number of younger citizens to fill entry-level positions since only 16 percent of the workforce would be between the ages of 16 and 24 by 2000[16]. To compound matters, high school students are not attracted to a lifetime career as a craft worker in the construction industry[17]. Conversely, this domestic labor shortage has resulted in employment opportunities for many immigrant workers. The construction industry is thus faced with a critical dilemma: the industry can either take actions to increase the supply of skilled labor (invest in vocational education; mount an aggressive image-building campaign; raise salaries and benefits; provide incentives to encourage skilled older workers to remain in the workforce); or it can lobby for expanded immigration policies, particularly the issuance of temporary worker visas. There are drawbacks associated with each of these measures[18]. But with the industry needing 240,000 new workers each year to replace those that are retiring or leaving[19] and the average age of a construction worker approaching 47 years[20], complacency is not an option. It is evident that some combination of the measures cited above must be enacted, and soon, to mitigate a worsening crisis in the construction industry.

Technology. Acceptance of new technologies[21] in the construction industry is moving slower than many industry experts would like[22]. The Chief Technology Officer of Black and Veatch (a $2.4 billion engineering and construction firm) notes that "firms are only using 5 to 10 percent of the technology capacity already in hand.[23]. A key obstacle to the adoption and use of IT is the fragmented nature of the industry, since with many parties involved in construction projects, barriers to the adoption of technology are multiplied. That said, it is clear that the future competitiveness of the construction industry depends on individual firms developing and adopting new technologies to secure competitive advantage in the future. That implies a greater investment in R&D and assumes that market conditions will become increasingly competitive so as to reward innovators who achieve efficiency gains through the use of technology and punish those firms which do not[24]. One solution may come from development of industry standards, adoption of performance metrics and a decrease in demand for paper legal documents. Once the industry takes these steps, IT will likely become as pervasive and as readily accepted as other new business practices (such as OSHA safety standards). The construction industry can make

this leap, but it will require leadership form the Architect/Engineering/Construction firms, both in the U.S. and abroad.

Infrastructure Financing. State and local tax revenues are declining while infrastructure development and maintenance costs are expected to rise. Public agencies have opted to privatize the provision of infrastructure construction and maintenance services because strains on their finances, project delivery schedules, and limited personnel resources have left them unable to meet the infrastructure demands of a thriving economy. Ninety percent of state agencies have been involved in some privatization of public services and 85 percent expect privatization to become a major tool in the coming decade. (See Case Study #1, below.)

GOALS AND ROLE OF GOVERNMENT

Government is a major player in the construction industry by virtue of its role as a provider of public infrastructure and facilities. But government also impacts the construction industry in other ways.

Many regulations, codes, and international standards have had a positive affect on the construction industry, especially in the area of quality and safety. However, other regulations and standards, primarily in the areas of environmental impacts, pollution abatement, Federal facility security, and minimum wage controls, have been more controversial. For example, some critics believe the Davis-Bacon Act artificially drives up labor costs thus reducing the number of government construction projects each year[25].

Government can do more to encourage R&D funding to keep the industry competitive and cost efficient. With the aging infrastructure in America, the Government needs to continue to allocate funding to cover infrastructure improvements as it did in the TEA-21 legislation. These investments are crucial to our nation's economic vitality. Government should continue to provide economic incentives to encourage construction and investments, especially in locations hit hard economically or by environmental contamination. We see more government tax incentives and less regulation as the better way ahead.

Finally, we believe government can help the construction industry by supporting U.S. construction companies abroad[26], negotiating free trade agreements with other countries and easing immigration policies to allow access to foreign labor. See **Policy Recommendations** section, below.

CASE STUDIES

The case studies which follow focus on three particularly topical issues affecting the construction industry in 2001-2002. The first concerns the industry response to the challenge of financing the development and maintenance of productive infrastructure. The second essay describes current trends in military-sponsored research and development aimed at improving the efficiency of field logistics and mobilization by reducing the Class IV materials footprint through the use of

innovative new technologies. The final essay summarizes the potential for new materials technology to mitigate the potential damage of future terrorist attacks on physical infrastructure.

Case Study #1 – Privatization

Privatization efforts in the U.S. have been motivated by efficiency considerations and budget shortfalls.

Efficiency Argument. Economic growth in the United States has fueled an incessant demand for improvements in the nation's infrastructure. State and local governments traditionally have relied on public-works agencies or departments for project delivery. However, the structure of these public authorities insulates them from the market discipline of private firms. They operate free from controls that exist either through the electoral checks of politics or the profit-maximizing interests of shareholders. Those to whom public authorities are responsive, such as bondholders, may have interests that vary significantly from the interests of the constituents whom public authorities are created to serve. The result is that public authorities will generally be less efficient than private firms that perform similar tasks.

Put differently, private firms providing public works facilities (e.g. airports, toll roads, water supply, waste water disposal) tend to be subject to much stronger economic incentives for efficiency than those that affect public authorities. Company managers often have a direct stake in the firm's profitability, and they can be replaced if stockholders become dissatisfied with their performance. Greater information disclosure in the private sector reinforces these incentive effects.

Budget Shortfall. The American Society of Civil Engineers estimates that America needs to invest $1.3 trillion, over the next five years to remedy critical infrastructure shortages and inadequacies[27]. Public agencies outsource because strains on their finances, project delivery schedules and personnel resources have left them unable to meet the infrastructure demands of a thriving economy. Although the ASCE estimate may be somewhat self-serving, other estimates of demand validate their conclusions. For example, the U.S. Department of Transportation estimates that highways and bridges need over $56 billion per year in investment over the next 20 years[28]; the General Accounting Office in 1995 estimated $112 billion in immediate needs for school maintenance and upgrades[29]; the National Education Association estimates school modernization needs at over $262 billion[30]; the Water Infrastructure Network estimates that an additional $23 billion per year for the next 20 years is needed to upgrade existing drinking water and wastewater treatment facilities to comply with environmental standards (taking effect between 2001 and 2004)[31]. Clearly the magnitude of the required investment forces public works agencies to seek new solutions.

Methodologies. Under the general rubric of private provision of public services, state and national governments have tried different methodologies to shift infrastructure responsibilities, in whole or in part from the public to the private sector. These include:

- Contracting[32] - in which a competition is held among private bidders to perform government activities. The government remains the financier and has management and policy control over the type and quality of services to be provided. The scope of services

that are contracted out is very broad. Practically every imaginable service has been contracted out in some community[33].

- Asset sale/divestiture - in which a government transfers ownership of assets or responsibilities to the private sector. Typically, the government has no further role in the financial support, management or oversight of a sold asset.
- Franchising - a franchise is created when a government agency provides exclusive rights to provide a service and precludes competition until the franchise period expires. The length of a franchise is largely dependent on the service provided and may vary from one year to more than 30 years. Local governments commonly grant private transit systems franchises to provide transportation services to the public. Users typically pay the contractor directly for providing a service. The government's role is to monitor the franchisee's compliance with the contract.
- Public-private partnerships – in which a government agency and a private investor share responsibility for the provision of services. The government retains control over the operation of a facility or program. Public-private partnerships are commonly used to design and operate public infrastructure facilities like water and wastewater treatment facilities.

Experience To Date. A 1998 survey of state governments conducted by Apogee Research[34] found that 90% of state agencies had been involved in some privatization venture and that 85% expected privatization to become a major tool in the coming decade[35]. Over 20% of states have or are working on a statewide or agency-wide privatization plan, including California, Maryland, Massachusetts, Michigan and Mississippi.

And the outsourcing wave continues to swell. A more recent survey of public works agencies[36] reported that:

- General services agencies in 22 states outsource building construction or facility maintenance functions;
- Transportation agencies in 34 states outsource highway design, road and bridge construction, road maintenance, architectural or airport services;
- Correctional agencies in 26 states and dozens of counties and cities have outsourced designing, building and/or operating correctional facilities; and
- Virtually all local governments outsource the design and construction of roads, bridges, solid-waste facilities, schools and water and wastewater facilities.

Public agencies have entered into these partnerships because of budgetary shortfalls, need for additional personnel for a limited duration, project delivery demands, and/or lack of in-house expertise.

There are a number of studies of cost savings from outsourcing infrastructure projects. Over 100 studies have documented cost savings from contracting out services to the private sector[37]. Among them, according to The Reason Public Policy Institute[38]:

- Outsourcing water and wastewater utility construction and management cuts costs by 10 to 40 percent. Outsourcing reduces the rate increases that were planned prior to privatization.
- Private companies build prisons and jails for "considerably less" than government agencies and in less time, while "dramatically reducing" operating costs.

- The cost of maintaining urban roads and highways can be cut by 25 to 50 percent through outsourcing.
- Design and construction costs for roads and bridges were lowest in states that used a mix of private and public sector work. Also, states that used contracting had a slower growth of design costs than did states that did not use contracting.

Pros and Cons. Cost savings aside, it should come as no surprise that the issue of privatization has vocal supporters and opponents. Advocates base their case on cost savings, innovation, efficiency and risk factors. Opponents argue that: 1) privatization causes policymakers to lose control over public services; 2) privatization diminishes the accountability of government; 3) privatization negatively impacts service delivery in the poorest or most isolated regions of the country, where profit maximizing is difficult; and 4) the cost savings data are methodologically problematic and overstated.

Critics of privatization point to the market failures that arose in the wake of deregulation and privatization of electric utilities in California in 2001; the lack of controls and abuse of prisoners' rights that occurred with some frequency after prisons were privatized in many states in the 1990s; and the poor track record of service in rural hospitals and nursing homes; certain telecommunications franchises and privatized railroads.

Legislative Provisions. Recent federal laws, rules and initiatives, especially the Government Performance and Results Act of 1993 (GPRA); the Clinger-Cohen Act of 1996; the revised handbook to the Office of Management and Budget (OMB Circular A-76[39]); and the National Performance Review (NPR) process have given new impetus to federal agencies to privatize aspects of their operations. These and other laws direct federal managers to review their programs by first considering whether government should perform a given activity – a step that often leads to privatization. Acts which specifically authorize privatization initiatives include: the Intermodal Surface Transportation Efficiency Act of 1991, President Clinton's Executive Order 12893 on Infrastructure and President Bush's Executive Order 12803 on Infrastructure Privatization. These Acts and Executive Orders supported the enactment of private toll roads and the sale of infrastructure assets such as airports, municipal gas and electric utilities, water systems and wastewater treatment plants.

A 1998 Law entitled: the Federal Activities Inventory Reform Act (PL 105-270 - the "FAIR Act") expands upon OMB Circular A-76 by listing government-provided services that must be reviewed for alternative delivery strategies, including divestiture and privatization. The FAIR Act is based on the premises that 1) competition saves money; 2) the government is in an ever-growing danger of falling further and further behind the private sector in the use and application of innovative processes and technology; and 3) with large percentages of the federal workforce approaching retirement, this is an opportunity to change "the very culture of government."[40]

More current legislative actions mirror the public debate about the merits of privatization. The House Committee on Government Reform, Subcommittee on Procurement Policy is currently debating an Act entitled the "Truthfulness, Responsibility and Accountability in Contracting" (TRAC) Act, H.R. 721. This Act is reflective of a growing sentiment against expanded use of outsourcing and privatization of government services. The TRAC Act prohibits any federal agency from making a decision to privatize, outsource, contract out or contract for the

performance of a function currently performed by such agency unless five requirements are met. They are: 1) safeguards are established to ensure effective contract administration; 2) a system is in place to monitor the costs, efficiency and savings of outsourcing; 3) agencies are allowed to hire additional federal employees when they can do the work more economically or efficiently than private contractors; 4) federal employees are allowed to compete for the provision of those services that are proposed for contracting out; and 5) the TRAC Act requires the Office of Personnel Management and the Department of Labor to compare the wages and benefits of federal employees and their contractor counterparts to ensure that private contractors do not offer substandard and unreasonably low benefits to employees. The sponsor of the Bill, Congressman Wynn, claims to have the bipartisan support of more than 185 Representatives.

Conclusions. In spite of the divisions in public and political opinion, privatization of government services and infrastructure will remain an important source of future employment for the construction industry. The budgetary constraints experienced by state and local authorities since September 11th provide further impetus to the expansion of public-private partnerships to deliver critical infrastructure requirements. In short, economics will trump equity concerns. Several research institutions have proposed recommendations to improve the processes by which privatization actions are undertaken. A GAO report[41] summarizes lessons-learned by state and local governments and suggests six measures to help ensure the success of the privatization process. They are: 1) identify political champions; 2) create an appropriate implementation structure; 3) enact legislative changes, as necessary; 4) track reliable cost data; 5) develop an effective strategy for workforce transition; and 6) create an autonomous monitoring and oversight unit. The Reason Public Policy Institute and the Comptroller of the Treasury have made similar recommendations. Each assumes that a continuing and accelerating shift from public to private provision of services and infrastructure will characterize the U.S. economy for the foreseeable future. (Brad Wallach)

Case Study #2 – Reducing Line of Communications (LOC)
Construction Engineer Footprint for Army Transformation Forces

At the request of the U.S. Army Engineer Research and Development Center (ERDC), the Construction Industry Seminar conducted a study to identify and recommend defense Research and Development (R&D) project concepts to reduce our military construction related "footprint" during foreign operations. This study results from the fact that the Army is transforming into an Objective Force characteristically defined as a more strategically responsive, agile, versatile, lethal, survivable, and sustainable land force capable of full spectrum land force dominance. A critical element in meeting these force characteristics requires the Army to find ways and means to implement reforms based on the findings of recent Total Army Analysis studies which identified the challenge posed by lift demand for construction material during deployment of Army forces. Characteristic themes of proposed concepts include improving the inter and intra-transportability of construction material and equipment with associated improvements in soldier flexibility in positioning and maneuverability. Reducing the construction "footprint" was not only considered in the sense of volume and weight, but also from defense related non-permanent presence perspective in an effort to maximize the agility of our fighting force. The three reports for this study recommend and identify project concepts designed to achieve lighter, more transportable, more flexible-use material and equipment. Specifically, these reports provide

recommendations in the barrier and fortification, line of communication and base development construction areas of study.

Barrier and Fortification. Specific concepts to reduce the logistics' footprint for barrier and fortification military related construction efforts include:

Sand Grids: The GeoGrid, or sand grid, produced by Presto Products, Inc., has not enjoyed widespread use, but does have broad applicability for use in constructing barriers and fortifications. A sand grid is a collapsible, high-density polyethylene honeycomb that is expanded and filled with local soil. The honeycomb holds the soil in place and these grids can be stacked on top of each other to form walls for bunkers and fighting positions, berms, and vehicle revetments. The size of the grid when filled with soil provides thicker wall protection than layers of sandbags.

Skid-steer Loaders: Buying and fielding a small piece of construction equipment that is versatile, mobile, and compact could make significant improvements in barrier and fortification construction while improving deployability of the force. The Bobcat would be ideal for quickly filling sand grids for building protective barriers. Significant manpower efficiencies could be gained by fielding this equipment and they could replace larger, heavier items in many units.

Plastic Concertina: With the technological advances that have been made in synthetic materials, it might be possible to make concertina wire from a type of plastic that could perform the same function as steel concertina with far less weight. Plastic can be made to be very tough and molded to have very sharp points. Plastic can be made in a variety of colors, including clear, that could be used to camouflage the wire so that defensive lines are less observable both to the eye and from aerial or radar surveillance.

Plastic Lumber: Considerable possibilities exist for the use of plastic to replace wood lumber and plywood. Corrugated plastic panels could substitute for plywood in some applications. It is lightweight, easy to cut and handle, and water proof. Since plastic lumber is a manufactured product, a wide variety of design techniques could be tried to improve strength, such as boards that are hollow with internal honeycomb baffles to save weight while increasing strength.

Infrared Detection Systems: The technology used in commercial security systems could be adapted for military use to reduce the amount of barrier materials used. An infrared light beam and a system of aimed reflectors could be employed to create a virtual barrier. If interrupted, an alarm system would be activated.

Synthetic Spider Silk Fibers: Scientists at Nexia Biotechnologies Inc. have been working with the Army's Natick Laboratories for years to develop man-made fibers with very high strength. They are getting close to producing a fiber made from the proteins in a certain type of spider silk. It is reported to be 3 times tougher than Kevlar and 5 times stronger than steel.

Rammed Earth Sandbags: A sand bag could be made strong enough to hold the weight of hydraulically rammed earth that would create a protective barrier denser than conventional sandbags. Potential materials would include the spider silk mentioned above. A ram could potentially be incorporated into the Future Combat System (FCS) to force moist soil into sandbags. The density of such a sandbag could be double or triple that of a traditional sandbag.

Line of Communication. Specific concepts to reduce the logistics' footprint for line of communication (LOC) military related construction efforts include:

Develop, test and evaluate smart, lightweight, efficient multi-use and modular LOC Objective Force construction engineer vehicle: The Army construction engineer force cannot continue to rely upon large, heavy and mostly one-dimensional construction equipment currently in use. This vehicle should have a common joint force chassis and capability to quickly connect and disconnect engineer attachments needed for specific missions. Civilian industry currently uses a similar vehicle known as the skid steer. They are accompanied with a large number of attachments and can perform a great many functions to include, hauling, dozing, grading and excavating.

Roads, Helicopter Landing Pad, and Airfield Soil Stabilization and Reinforcement Concepts: The military engineer continually faces the challenge to stabilize soil to meet a myriad of tasks in austere theaters of operation. Currently, cement and the associated ingredients to make concrete provide the basic means used for such stabilization tasks. However, the following materials offer a more efficient and effective means by reducing the transport weight and volume of material demands currently required for cement and the water used to cure the soil-cement mixtures.

Sand Grid (Geocell): The Geocell is lightweight, easy to transport and install, does not require special handling for weather conditions and maximizes use of indigenous soil material.

Synthetic Fibers: These fibers offer a lightweight and easily transportable means to provide cohesion of granular soils. Current fiber reinforced soil application techniques require use of heavy legacy construction equipment to prepare the soil-synthetic fibers mixture; however, this report recommends integration of the above lighter and smarter Objective Force construction equipment.

GeoSynthetic Membranes/Textiles: Geosynthetic manufacturing and use in soil stabilization has advanced tremendously over the past 15-20 years. These materials offer multi-functional use, ease of transport and adaptability to a variety of indigenous soil conditions and weather patterns.

Lightweight Plastic Culverts: Steel culverts are still a common item for planning and use in military construction. Plastic culverts are approximately 60% the weight of similar size steel culverts, have a life expectancy beyond the military's 2-5 years and are in common use in the civilian sector of the industry.

Information Technology Systems To Effectively Manage LOC Construction Data: Current technological advancements and ongoing studies at the National Imagery and Mapping Agency (NIMA) establish prudence to develop smart ground based systems in the military's family of vehicles for terrain and soil condition data collection. The ground-based system should be small, durable, user friendly for automatic data collection transparent to the solider in the field and linked to air and space based data collection systems. Such a system to collect and analyze data with smart software based programs enables automatic solution of engineering tasks that currently require survey equipment and intensive man-hour analysis.

Bridge Enhancement Retrofit Materials and Application Techniques: Current studies on the use of externally bonded synthetic fibers and polymer-resin matrix composites deserve further analysis as a viable lightweight and quick means to retrofit damaged structures such as bridges. This technique provides quick solution and decreases the demand for personnel and equipment to repair damaged structures.

Base Development. Specific concepts to reduce the logistics' footprint for base camp development and construction include:

Use plastic/composite structural members in lieu of metal or wood. Substituting metal or plastic studs for wood can reduce weight by 25% and loaded space up to 40%.
Use prefabricated plastic flooring for floors, decks and walkways. Products such as EcoTrack® panels can provide large, all-weather surfaces that can be rapidly deployed. It is not only 1) lighter than plywood flooring or concrete walks, it is 2) faster to install (better supports the mission), 3) more durable, 4) requires minimal training and 5) has multiple applications.
Implement the use of expedient composite shelters for refugees. The Deployable Structures Team at Oxford University has developed a structure that is strong, economical, versatile, capable of rapid assembling and deployment, and meets all pallet size requirements for U.S. transport aircraft. Such structures could be stockpiled and used in emergencies. They also fold up in nice, neat packages.
Use plastic fencing around generators and power sources in lieu of metal or wood constructed enclosures. Current Army planning mandates enclosures be constructed of metal or wood. These materials provide little structural deterrence. Using plastic fencing will save time, money and reduce the shipping footprint.
Utilize plastic (PVC) piping throughout the base, except in certain POL applications. Weight savings is 50-100% and with today's popular applications, craftsmen can work with PVC more easily than with heavy metal.
Use plastic in lieu of metal or wood signs. Commercial companies such as 3M manufacture plastic and composite sign material that is lightweight, strong and come in a variety of colors. It is currently being used today at major stateside installations.
Use growth retardant materials for vegetation. Studies have shown environmentally neutral chemical application can reduce vegetation growth over 60%. This represents a significant savings in maintenance man-hours and equipment.
Increase use of personal data assistants (PDAs) within deployed engineers and craftsmen. PDAs are extremely useful in managing material assets, manpower, and facilities. Environmental reports, facility inspections, and equipment management can be automated and linked via wireless technology to a shared database for improved command management. To take it another step, the Air Force is developing GeoBase technology which links hard physical data with GPS imagery to allow for quicker, more informed base camp decisions.
Improve on an already proven technology—sandbags. The use of automated sandbagging machinery can produce 30-40 times the number of conventional sandbags using traditional technology.
Design structures whose containers can serve as a bunker. The crux of the issues here is to transition from the use of traditional metal containers (CONEX boxes) and into something lighter, more flexible with alternative uses after shipping.

(William Perkins, Paul Meredith, Michael Smietana)

Case Study #3 – Hardening of Barriers and Fortifications for Homeland Defense and U.S. Sovereign Territory Overseas

The United States has established a significant presence around the world through its embassies, military deployments, and private enterprises. Unsurprisingly, not all peoples and governments

of the world support US government policy and its global presence. Consequently, the United States faces increasing threats to its critical and representative infrastructure at home and abroad from terrorist actions and other hostile activities, as evidenced by bombings of the World Trade Center in1993, Alfred P. Murrah Federal Building in Oklahoma City, embassies in Kenya and Tanzania, and the USS Cole. The culmination of these aggressions was the 11 September 2001 airplane hijackings and attacks on the World Trade Center and Pentagon. Despite these attacks, current US policy of remaining globally engaged has not wavered and will continue as its "overseas representatives [are] on the front line of efforts to build support for democracy, to maintain peace, and to promote prosperity around the world."[42] To ensure the safety of our representatives at home and abroad, the US must upgrade existing and future facilities to meet force protection requirements. This case study investigates current research initiatives and identifies current, near term, and future materials that could be used to harden facilities and improve the safety and survivability of building occupants.

A working draft of the *Department of Defense Antiterrorism Standards for Buildings* identifies seven design strategies for construction and renovation projects: maximize standoff distance, prevent building collapse, minimize hazardous flying debris, provide effective building layout, limit airborne contamination, provide mass notification, and facilitate future upgrades.[43] This case study focuses on research and development initiatives for preventing two of these strategies: building collapse and minimizing hazardous flying debris.

Any discussion on force protection and building survivability would be incomplete without referencing the Pentagon in Washington, D.C., as it has been widely heralded for its performance during the 11 September 2001 crash of a Boeing 757 into its west side. The resulting devastation could have been much worse had improvements from the Pentagon Renovation Program not been recently completed on this section. Blast resistant windows with glass almost 2 inches thick and an inner protective film were immediately adjacent to the impact area did not fragment during the impact and explosion thus increasing the occupant's chances of survival by dramatically reducing the number of injuries and time and effort required to care for them.[44] In addition, the original and renovated building construction used spiral rebar in lieu of straight rebar for concrete that strengthened the overall structure.[45] Another structural enhancement was a web of 6-by-6 inch steel columns on all levels bolted to the ceiling and floor forming a continuous unit from top to bottom.[46] Finally, the renovated area included blast-resistant material**,** similar to Kevlar, "stretched between the steel beams to prevent debris from becoming shrapnel in the event of an external explosion."[47] The Pentagon's performance during the 11 September attack provides strong evidence that current technology exists to enhance facility and occupant survivability during a catastrophic event.

Preventing Building Collapse. Generally, two categories are used to describe high performance building materials – polymer composites and enhancements to traditional materials. Polymer composites, when fully developed for the industry, have the potential to replace traditional construction materials, such as concrete, steel, and timber. Enhancements for traditional construction materials are also being developed by combining two or more traditional materials, or traditional materials with a polymer composites, that in aggregate is stronger, lighter, or more durable.

Polymer Composites are materials "whose engineering performance – high strength, good corrosion resistance – can exceed that of traditional materials while reducing the weight,

maintenance expenses, and operating costs." They "typically combine the lightness of a polymer with the stiffness and strength of high performance fibers, such as glass or carbon reinforcing fibers." Composites are not widely used in construction yet as they are still "too labor intensive or too product specific to work efficiently in larger volume commercial settings."[48] The National Institute of Technology and Standards (NIST) Advanced Technology Program (ATP) and the United Kingdom (UK) Department of the Environment, Transport and the Regions (DETR) are conducting significant research into the strength, durability, manufacturing, and application of polymer composites in construction. Strongwell Corporation, working with NIST, has manufactured prototype 8" high bridge beams from "glass and carbon fibers bound by a resin," which tested well for fatigue, creep, and strength, and is working on a 36" beam. NIST has another success story with Ebert Composites Corporation. Ebert has cost-effectively manufactured and installed composite power transmission towers by using interlocking joints for a "snap and build" assembly process and reduced production time 90% by combining pultrusion and computer numerical control machining. Southern California Edison Company has determined the initial installation cost to be comparable to steel towers, but the annual maintenance cost is $700 less per tower.[49]

Enhancements to traditional materials use polymer composites in combination with a traditional material, or two or more traditional materials together, to add strength, lightness, or durability. As with polymeric composites, high performance traditional materials have been developed, but their application is not widespread due to issues regarding longevity and fire resistance. For example, "high grade concrete has a lower permeability than normal concrete, which means it can suffer explosive spalling during a dire (sic) due to its inability to dissipate the steam pressures that arise."[50] To address this issue, NIST and DETR sponsor several initiatives investigating various concrete additives to improve fire performance while maintaining high strength. (Unfortunately, results of DETR projects are not available via the Internet and must be acquired from the performing contractor.)

An interesting alternative to using polymer composites as a cement additive is a system that uses a "series of 6" x 9" x 5/16" pultruded fiberglass tubes filled with concrete to form a bridge deck. The fiberglass tubes … act as a concrete form [and] prevent cracking and corrosion of the concrete, lend added stiffness to the deck, and reduce the dead load of the system.[51] Additional concrete enhancements include composites with other traditional materials, such as steel, which could improve construction speed, add strength, and minimize flying debris if used in wall construction. Enhancements to traditional materials hold a great deal of promise for increasing the survivability of facilities and should be considered for further research.

Japan is conducting extensive research into the use of paints to aid structural integrity, fire protection, and heat resistance. (Although no specific programs or information could be found during research for this case study, trade journals have reported on their efforts.) In an interview with *Engineering News Record*, Professor of Construction Management at the University of Reading, UK, Roger Flanagan, indicates the Japanese have developed paint designed to bind buildings during seismic activity. "Their problem is earthquakes, our problem is terrorism, but the impact is the same," he said.[52] In a review of the Japanese paint industry, *Chemical Week* identified work on new "intumescent epoxy coatings that protect structures from fire by bubbling and expanding when exposed to heat. The expansion results when gases are generated but entrapped in the coating's polymer matrix."[53] When contacted by the author, the International

Paint & Printing Ink Council (co-located with the National Paint & Coatings Association) in Washington, D.C., indicated they were sending a representative to Japan during the week of 1 April 2002 to investigate these specific research initiatives.[54] While these paints, in isolation, will not prevent building collapse, they may provide an inexpensive and effective retrofit to aid stability and retard fire spread allowing additional time for building occupants to escape.

Interesting research is being conducted into several technologies that could significantly enhance structure stability in the future. None of these technologies will be commercially available in the near term, however it is important to consider their potential when considering long-range plans. Nanotechnology will affect far more than the construction industry, however its potential for construction is significant. It is easy to envision using nanotechnology to create new classes of strong, lightweight structural materials with concrete, steel and polymers as the base material. Imagine concrete six times stronger, "self-healing cracks, paint-on deformation sensors, stronger metals, corrosion 'antibodies' and corrosion-mending nanobots, porosity modifiers, auto-modulous correctors."[55]

"Smart" materials are being researched for use with concrete. The State University of New York in Buffalo is mixing specially treated carbon fiber into cement to enhance electrical conductivity – when the "smart" concrete is compacted, conductivity is reduced and when the pressure is removed, conductivity is restored.[56] The Canadian Institute for Research in Construction (IRC) is researching an alternative approach. The IRC believes a conductive aggregate using a form of coke that is a byproduct of steel manufacturing (porous coke) is more cost effective, and can be used to heat buildings by connecting it to an electrical source.[57] It is conceivable to use this technology to monitor buildings for stress as they shift in winds or because of external pressures such as an explosion. Careful monitoring could give building managers and rescue personnel "real time" indications of when and where collapse points may occur. Another possible application of electrically conductive concrete is to use it as electromagnetic shielding, stopping adversaries from monitoring computer emanations,[58] or possibly to provide protection from electromagnetic pulses.

Perhaps the most exciting future technology is the production of the first spider silk fibers from man-made materials by Nexia Biotechnologies Inc., in partnership with the U.S. Army Soldier Biological Chemical Command (SBCCOM).[59] Manufactured by "inserting spider silk genes into cells of hamsters and cows and squeezing the resulting proteins into a gossamer fine thread. Ounce for ounce, it's three times tougher than Kevlar … and five times stronger than steel."[60] As this man-made spider silk has characteristics similar to Kevlar (except it's stronger), its potential uses are also similar – as an additive to create high strength concrete, fabrics for clothing and tents, and as a curtain to minimize flying debris.

Minimizing Hazardous Flying Debris. "Nearly three-quarters of the injuries from the 1995 bombing of Oklahoma City's Alfred P. Murrah Building were caused by flying glass."[61] Consequently, the search for methods to prevent glass fragmenting into dangerous projectiles has picked up speed over the past several years. Window interlayers, laminates, mullions, frames, and anchors are all being tested to meet higher standards, even up to the 4,000 psi the exterior walls of Murrah building were hit with. Current designs include the two year old Las Vegas U.S. courthouse that utilizes a "1-in.-thick insulated, blast resistant unit … composed of standard, annealed exterior glass; a ½-in. air space; and, on the interior surface, a laminate of polyvinyl

butyral between two sheets of 1/8-in.-thick annealed glass held in place by aluminum frames." [62] Two comparatively easier fixes for existing buildings are to apply film to the inner windows, as was done in the renovated sections of the Pentagon, to help withstand overpressures or install replacement laminate windows.[63] Window film is cheaper than laminate windows, but less resistant to blast.

If the installation of protective film on window interiors is not feasible, or additional protection is desired, then protective curtains that catch glass and concrete fragments are feasible. Special curtains, manufactured from high strength fabrics, can be hung over windows to prevent injuries from flying glass.[64] The Pentagon effectively used Kevlar cloth installed between windows in the renovated sections to minimize flying concrete fragments.[65] The team designing a new Seattle courthouse is "working on a blast-resistant curtain wall that will absorb and dissipate the impact of a blast 'like bubble gum, or like a spider web' … similar to a cable-supported system Seele installed recently at the University of Bremen."[66]

Conclusion. The tragic events of 11 September 2001, coupled with past attacks on sovereign U.S. territory, have given additional impetus in finding ways to protect our citizens and representatives around the world. The United States must not waver in the face of these tragedies and should remain globally engaged to promote the principles upon which this country was founded. As evidenced by the ability of the renovated section of the Pentagon to survive the impact of a Boeing 757, technology exists today that can significantly improve building and occupant survivability. For the future, research and development into construction materials and techniques that can assist in protecting U.S. facilities at home and abroad is ongoing internationally. Some of the most promising: polymer composites, enhancements to traditional materials, seismic and fire/heat resistant paint, nanotechnology, "smart" materials, man-made spider silk fibers, strengthened windows and frames, ethyl tetra fluoro ethylene, protective curtains, curtain walls, building layouts, HEPA filters, and ultraviolet-C emitters are outlined in this case study and recommended as investment opportunities for government research laboratories. (Kenneth Eads)

IMPLICATIONS FOR NATIONAL SECURITY

In the future the capacity of the construction industry to surge during periods of crisis could be constrained by chronic labor shortages. Calling up reserves or drafting civilians will be policy options if the threat is severe enough.

That said, there are precedents for the use of short-fuse contracting mechanisms to mobilize private sector providers of needed services during crises. The Port Authority of New York used a time and materials letter contract to procure site clean-up services after the 9/11 attacks.

The U.S. depends on imports for more than 40 percent of all construction equipment[67]. This represents a potential vulnerability during times of war when transportation links may be disrupted and foreign sources of equipment may be unavailable or more costly.

POLICY RECOMMENDATIONS

The construction industry currently has minimal government oversight and regulation. The primary interaction between government and industry are established building codes and inspections. Codes are localized to address issues specific to the location in which construction is taking place. For example, California building codes are generally more robust than other parts of the country due to the need for building structures resistive to earthquakes. Due to the large number of design and engineering companies across the nation, as well as the highly competitive environment for general and specialist building contractors, there is no need for the government to oversee or regulate the industry as it does in other highly concentrated sectors, such as shipbuilding and munitions. Consequently, we do not recommend significant government policy that will affect the construction industry at large, but we do offer a few minor recommendations to ensure the industry remains healthy and robust.

Temporary Work Visas for Skilled Labor. The current strength of the U.S. economy has resulted in an increased volume of construction projects throughout the country and growth in the industry is expected to continue, as civil infrastructure requires replacement or upgrades. This puts additional pressure on construction companies to hire and retain skilled labor, which is increasingly difficult to find in the U.S. market. While the industry is already using significant numbers of immigrants to fill the void, many more will be needed. To encourage foreign laborers to come to the U.S., the seminar supports increased use of temporary work visas focused on skilled construction trades.

Increased Investment in R&D. In every industry, research and development is important to ensure continued competitiveness by leveraging technology, fostering innovation, and ensuring worker safety. The construction industry is no exception. However, current investment in construction R&D is seven times below the national average. Most construction R&D is related to materials, procedures, and safety. The events of 9/11 have also added R&D aspects for building security and protection. R&D is expensive, and, to encourage further efforts, we propose a two-pronged approach. First, tax incentives for private companies to give them help in defraying the high costs. Second, to encourage government-industry partnering to focus efforts and reduce redundancy.

International Market Access. The ability of U.S. design-engineering firms and construction companies to participate in international projects supports their long-term growth and innovation. Entry standards for U.S. firms in a wide array of foreign projects and host government support for international firms vary from country to country, with some key markets being extremely restrictive. The U.S. government can exert bilateral pressure in some cases to modify restrictive practices, but this is a long-term process. It is widely recognized that some governments, such as Japan, support their international construction companies by providing assistance in the form of Official Development Assistance, which can allow Japanese companies to gain non-competitive advantages, often in a non-transparent manner. The U.S. should expand the “war chest” at the U.S. Export-Import Bank both to compete with foreign tied-aid practices, and to serve as a negotiating tool. The United States should, as a matter of course, continue its efforts to reduce or remove barriers to services trade through the intermediary of the WTO and other international bodies.

Critical Infrastructure Investment. The American Society of Civil Engineers recently published a study entitled "Report Card for America's Infrastructure" which reviewed the condition of our roads, bridges, transit, aviation, schools, drinking water, wastewater, dams, solid waste, hazardous waste, navigable waterways, and energy. The study found that, on average, our critical infrastructure rates a "D+" and requires a total investment of $1.3 trillion over 5 years to correct significant deficiencies. The study concluded that three factors contribute to these poor conditions: 1) population growth, 2) local opposition and red tape, and 3) general aging. United States Federal, state, and local governments need to budget sufficient funds for capital repair and expansion projects to correct identified deficiencies and sponsor a biannual review of our critical infrastructure to ensure we remain ahead of our needs.

CONCLUSIONS

The construction industry forms the backbone of many industries and the economy as a whole. The industry has significant surge capability, as demonstrated by the expeditious repair of the Pentagon and clean up of the World Trade Center site. The future of the construction industry is bright. New growth combined with our aging critical infrastructure that needs repair and/or replacement provides plenty of opportunity; however, industry growth will cycle with the overall economy and interest rates.

America's longest ever period of economic prosperity ended during the third quarter of 2001 after ten years of uninterrupted economic growth. While the most likely scenario is that the U.S. economy will grow very little during 2002, the construction industry is expected to sustain modest growth. The strongest sectors for 2002 include new construction in education; health care; single-family homes and apartment buildings; retail buildings focused on consumer basics, such as grocery-store-anchored strip malls and discount department stores; back capacity for critical functions; and security-enhancing renovation projects for all existing private and public buildings. Despite the forecasted imbalances in the future growth of the various construction sectors, the medium-and long-term economic outlook for the construction industry remains decidedly positive.

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[1] McGraw-Hill Companies and U. S. Department of Commerce/International Trade Administration, *U. S. Industry and Trade Outlook*. McGraw Hill Companies. New York, New York: 2000, p. 6-1.

[2] U. S. Department of Labor, Bureau of Labor Statistics, *Table of Industry Employment, 2001,* Online. Internet: March 2002, p. 1. http://data.bls.gov/cgi-bin/surveymost.

[3] U. S. Department of Labor, Bureau of Labor Statistics. *Career Guide to Industries: 2002-2003 Edition.* Online. Internet: March 2002, p. 1. http://www.bls.gov/oco/cg/cgs003.htm

[4] Ibid, pg 2.

[5] Gale Research, *U. S. Industry Profiles: The Leading 100,* Gale Research. Detroit, Michigan: 2000, pg. 194.

[6] Baumol, William J. and Alan S. Blinder, Economics: Principles and Policy, Eighth Edition, Harcourt College Publishers, Fort Worth, Texas: 2000, p. 367.

[7] RAND Corporation, *Summary of Federal Construction, Building, and Housing Related Research & Development in FY 1999,* Online. Internet: February 2002, p. 12. http://www.rand.org/publications/MR/MR1390/

[8] U. S. Department of Defense. *Details for Fiscal 2003 Department of Defense Budget Request*, Online. Internet: February 2002, p. 11. http://www.derfenselink.mil/cgi-bin/dlprint.cgi, and
American Association for the Advancement of Science (AAAS), *AAAS Final FY 2002 R&D Appropriations Funding Update*. Online. Internet: February 2002, p. 3. http://www.aaas.org/spp/R&D

[9] Recent data (various informal sources) suggest a slowing in new construction starts.

[10] Simonson, Ken, *Construction Employment Shrank in January; Value of Construction Held Steady in December*, The Data Digest. Associated General Contractors of America. Arlington, Virginia: 2002, p. 1.

[11] Tulacz, Gary and William Krizan, *The Top 600 Specialty Contractors*, Engineering News-Record. McGraw-Hill Companies. New York, New York: October 8, 2001, p. 1.

[12] Confederation of International Contractors' Association, *U. N. Environmental Program Report - Industry as a Partner for Sustainable Development – Construction.* Beacon Press. London, England: 2002, p.7.

[13] Tulacz, Gary, *A Look at a $3.4 Trillion Market*, Engineering News-Record. McGraw-Hill Companies. New York, New York: December 4, 2000, p.30.

[14] The top five construction firms (as measured by annual construction revenue generated) are multi-billion dollar companies. According to the most recent survey by Engineering News-Record , August 20, 2001, the top five U. S. contractors, in rank order are: 1) Bechtel Group Inc. of San Francisco, California; 2) Fluor Corporation of Aliso Viejo, California; 3) The Turner Corporation of Dallas, Texas; 4) Centex, of Dallas, Texas; and 5) Skanska USA of Whitestone, N.Y. Bechtel is privately-owned, employs 50,000 people and booked $14 billion in new business in 2000. Fluor Corporation is publicly-owned, also employs 50,000 people and generated $9.6 billion in new contracts in 2000. Turner Corporation is now a wholly-owned subsidiary of the German firm Hochtief AG. With a staff of 4,000, Turner booked $6 billion in new contracts in 2000. Skanska USA is owned by Skanska, Sweden, employees 79,000 worldwide and generated $6.5 billion in new contracts in 2000. Centex, with 15,000 employees, generated $8 billion primarily in homebuilding sales in 2000 and is publicly traded on the New York and London Stock Exchanges.

Many large firms have grown to their current stature through acquisitions. A recent example is Skanska's acquisition of the U. K. operations of Kvaerner PLC, formerly the second-ranked international contractor (in 2000) with $6.4 billion in international revenues. According to Engineering News-Record , August 20, 2001, p. 28, almost 50% of Skanska's revenue in 2000 came from U. S. acquisitions, compared to 30% in 1997.

[15] In 1999, the Associated General Contractors (AGC) surveyed over 700 general contractors; eighty-six percent of respondents indicated that the shortage of trained workers is the greatest challenge facing their firms and the industry at large. This figure had increased from 48% reported in a similar 1995 survey. See: *Statement Submitted on behalf of the Associated General Contractors(AGC) of America to the House Small Business Committee.* Online. Internet: March 2002, p. 3, http://www.AGC.org/Legislative_Info/Members_Testify/testimony_02-09-00.asp, and the Construction Industry Institute (CII). *Research Reports - 2001*. Online. Internet: March 2002, p. 3. http://www.construction-institute.org/services/catalog/ressum.cfm.

[16] Piper, Christine and Roger Laska,. *Clemson University Attracting And Retaining A Skilled Construction Workforce*, ASC Proceedings of the 36th Annual Conference. Online. Internet: March 2002, pp. 277-286. http//asceditor.unl.edu/archives/2000/piper00.htm

[17] In a 1998 Wall Street Journal poll, high school age students were asked to place different career choices in rank order of preference. Construction work ranked 248th out of 250 possible occupations, ahead of only "dancer" and "lumberjack". This is indicative of a general perception that construction workers lack prestige and respectability. See: Shelar, Scott, *Labor Shortage Threatening U. S. Construction Industry*, Atlanta Business Chronicle, September 4, 1998. Online. Internet: March 2002, p. 1. www.amcity.com/atlanta/stories/08/18/97/story8.html.

[18] Expanding immigration policies to accommodate more skilled and semi-skilled workers raises complex and controversial social integration issues. Providing further tax cuts to offset training costs for small businesses could effectively reduce demand for the remaining union-organized training and apprenticeship programs and contribute to the decline of the union membership. Increasing the availability of vocational and technical education opportunities will have limited impact unless such initiatives are accompanied by substantial increases in comparative wages and benefits and an effective image building campaign to attract ambitious young entrants into the construction trades. Increasing incentives for older workers to remain in the workforce potentially "crowds out" opportunities for younger workers to advance in the trades.

[19] U. S. Department of Labor, Bureau of Labor Statistics, *Aging of the Workforce*, Engineering News-Record, June 19, 2000. McGraw Hill Companies. New York, New York: p. 52.

[20] Ibid, p. 52.

[21] Examples of IT applications in construction include: 1) communication tools (intranet, email systems); 2) manufacturing tools ("computer-aided manufacturing"); 3) project management tools (critical path, project progression, billing and bidding software); 4) training tools (online or distance learning); or 5) design tools ("computer-aided design").

[22] In an interview, the CEO of Bentley Systems (a leading provider of construction information technologies) stated: "There is no one who thinks that the revolutionary benefits (of IT) are behind us…this is not for want of technology or tools, but for want of adoption and use." See: *Future of IT*, Engineering News-Record, December 31, 2001. McGraw Hill Companies. New York, New York: pp. 36-38.

[23] Ibid.

[24] Currently, non-productive (non-billable) time in the U. S. manufacturing industry runs at 16% while that number in the construction industry runs at about 50%. This represents an area for real profitability enhancement, says James Adrian, a Civil Engineering and Construction Professor at Bradley University. See: *Construction Industry Productivity*, Engineering News-Record, November 8, 2000. McGraw Hill Companies. New York, New York: p. 45

[25] The Davis-Bacon Act, as amended, requires that each contract over $2,000 to which the U. S. is a party, for the construction, alteration, or repair of public buildings and public works, shall contain a clause setting forth the minimum wages to be paid to various classes of laborers and mechanics employed under the contract. The Act directs the Secretary of Labor to determine and mandate the use of local prevailing wage rates.

[26] The U. S. Government has a wide range of tools for supporting U. S. construction companies abroad. The conventional wisdom has been that the large size of U. S. international construction companies justifies most companies' creation of separate market information networks, so U. S. Government intelligence is not a critical factor. But for the smaller and medium-sized companies, officially-sourced information is still quite important in identifying market opportunities. The U. S. Department of Commerce is the principal source of such information and continues to generate reporting through its Foreign Commercial Service operations. The Commerce Department performs an advocacy role for U. S. companies abroad, often including face-to-face project advocacy by top Commerce Department officials with their foreign counterparts. Ex-Im Bank export credits and investment insurance, OPIC investment guarantees and project financing, and Trade Development Agency (TDA) financing for project feasibility studies are other examples of U. S. Government support for construction firms operating overseas.

[27] American Society of Civil Engineers (ASCE), *Renewing America's Infrastructure: A Citizen's Guide, 2001*. ASCE. Arlington, Virginia: 2001, p. 4.

[28] U. S. Department of Transportation (DOT), Federal Highway Administration, *1999 Status of the Nation's Highways, Bridges and Transit Conditions and Performance.* DOT. Washington, District of Columbia: 1999, p. 6.

[29] General Accounting Office (GAO), *School Facilities: The Condition of America's Schools.* GAO. Washington, District of Columbia: 1995, p. 12.

[30] National Education Association (NEA), *Modernizing Our Schools: What Will it Cost?*, NEA. Washington, District of Columbia: 2000, p. 9.

[31] Water Infrastructure Network, *Clean and Safe Water for the 21st Century*, Water Infrastructure Network. Washington, District of Columbia: 2000, p.3-3.

[32] State and local governments in the U. S. currently contract for over $200 billion in services every year. Many services traditionally provided by governments are now delivered by private enterprises, including prison management, fire management, transportation, wastewater operations health care and public schools. See: Reason Foundation, *Eleventh Annual Report on Privatization*. Reason Foundation. Washington, District of Columbia: 1998, p. 2.

[33] A complete list is available at. See: Finley, Lawrence, Public Sector Privatization: Alternative Approaches to Service Delivery, Quorum Books, New York, New York: 1989, p.7.

[34] Apogee Research, based in Washington D.C., is an independent, non-profit organization devoted to research in public affairs.

[35] Reason Foundation, *Eleventh Annual Report on Privatization*, Reason Foundation, Washington, District of Columbia: 1998, p 4.

[36] Chi, Keon and Cindy Jasper, *Private Practices: A Review of Privatization in State Governments.* Council of State Governments, Lexington, Kentucky, 1998; p. 6, and Burgiel, Jonathan. *Trends in Privatization and Managed Competition: National Survey Results,* R.W. Beck Publishers, Seattle, Washington: 1998, p. 23.

[37] A chart summarizing the findings of over 100 studies on privatization can be found. See: Hilke, John, *Competition in Government-Financed Services*, Quorum Books. New York, New York: 1992, p. 27.

[38] Moore, Segal and McCormally, John. *Infrastructure Outsourcing - Policy Study No. 272.* Reason Foundation. Washington, District of Columbia: 1998, p. 2.

[39] OMB Circular A-76 sets forth federal policy for using commercial services. In March 1996, OMB revised the circular, requiring agencies "to enhance federal performance through competition and choice, seek the most cost-effective means of obtaining commercial products and support services, and provide administrative flexibility in agencies' decisions to retain services in-house or contract them out."

[40] Sessions, Congressman, *Testimony before the House Committee on Government Reform*. U. S. Congressional Record. Washington, District of Columbia: June 28, 2001, p. 3.

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